Measuring Neutrino Cross Sections on Argon for Supernova Neutrino Detection

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The measurement of the time evolution of the energy and flavor spectrum of neutrinos from supernovae can revolutionize our understanding of neutrino properties, supernova physics, and discover or tightly constrain non-standard neutrino interactions [1,2,3]. The Long Baseline Neutrino Experiment, which will include a 10 kTon liquid Argon Time Projection Chamber (LArTPC) far detector, has the capability to make precise measurements of supernova neutrinos. For example, collective neutrino oscillations imprint distinctive signatures on the time evolution of the neutrino spectrum that depend, in a dramatic fashion, on the neutrino mass hierarchy and mixing angle theta13. Current knowledge of the neutrino argon cross sections and interaction products at the relevant energies (<50 MeV) (there are no neutrino measurements in this energy range) would limit the ability of detectors to extract information on neutrino properties from a supernova neutrino burst. Cascades of characteristic de-excitation gamma rays are expected to be associated with different interaction channels, which could enable flavor tagging and background reduction. Currently the ability of LArTPC detectors to observe these gammas is unknown. The LArTPC we are building will afford a nearly unique opportunity to measure key neutrino-nuclear cross sections in both the charged and neutral current channels that would allow us to make better use of the supernova neutrino burst signal.

A five-ton fiducial mass LArTPC is being built at LANL using internal laboratory funds. The chamber consists of three active wire planes with 3mm pitch and 3mm wire spacing. The detector volume is a hexagonal prism with a 1-meter height and 1 meter apothem. The hexagonal prism is oriented with the hexagon in the horizontal plane. The electric field is oriented in the vertical direction with the electron drift upwards. The readout is performed with cold electronics developed for LBNE and MicroBooNE. The detector is described in [4].

We propose to run this LAr TPC at the SNS to measure these cross sections and determine the capability of a LArTPC to detect the de-excitation gamma rays. The Spallation Neutron Source in Oak Ridge, TN, provides a high-intensity source of neutrinos from stopped pions in the mercury target, of well-known energy spectrum with energies up to 50 MeV. The timing characteristics of this source are excellent for rejection of background [5] (which would need to be measured). The interaction rates in argon are shown in Fig. 1 as a function of distance and argon mass [6]. A five-ton detector would measure thousands of events per year if sited sufficiently close to the target. Neutrino interaction cross-sections in argon and interaction product distributions, including de-excitation gammas, could be measured for the first time. Such an experiment would also be valuable for understanding the response of a LArTPC detector to neutrinos in this energy range.

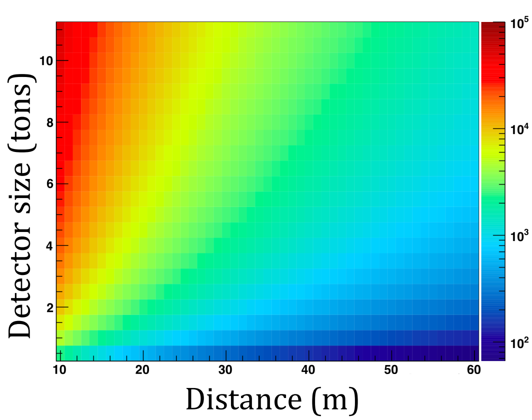

Figure 1: Estimated interaction rates, in events per year, in argon as a function of detector mass and distance from the SNS target.

References

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